DATA COMMUNICATION APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATION

The present invention claims the benefit under 35 USC §119(e) of prior U.S. provisional patent application Serial no. 60/448,459 to Rabipour et al., filed February 21, 2003, incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates generally to communications networks and, more particularly, to methods and apparatus for increasing the service quality and efficiency with which data is communicated between entities in such networks.

BACKGROUND OF THE INVENTION

According to most existing telecommunications standards, the transmission of speech information over a wireless interface takes the form of compressed speech parameters. Upon receipt of compressed speech parameters at a base station in communication with a mobile unit, the speech parameters are processed by a codec (coder / decoder), which converts (expands) the speech parameters into speech samples, typically at a rate of 64 kilobits per second (kb/s) in order to provide compatibility with the public switched telephone network (PSTN). The speech samples at 64 kb/s are then transmitted over the PSTN towards the called party. The speech samples associated with a given call may share the same link as speech samples associated with other calls by virtue of time division multiplexing (TDM), which provides for fixed-duration time slots to be allotted to individual calls.

If the called party is connected directly to the PSTN, such as via a wireline connection, the speech samples having travelled through the network will simply be converted into audio form by a digital telephone unit at the called party site. Of course, the called party may also be a second mobile unit, in which case the speech samples will terminate at a second base

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station, where a second codec re-converts the speech samples back into compressed speech parameters for transmission to the second mobile unit via a wireless interface. The usage of a source decoder to expand speech parameters into a stream of speech samples, in combination with the use of a destination encoder for re-compression of these samples into a second set of compressed speech parameters, is referred to as operation of codecs in tandem, or "tandem operation".

Those skilled in the art will appreciate that when both the called and calling parties are mobile units, the tandem operation described above introduces a degradation in service quality, as errors may be introduced by the decompression and re-compression operations performed by the source and destination codecs, respectively. Such error should in principle be avoidable, as neither codec operation is required by virtue of the second base station requiring the compressed speech parameters rather than the expanded speech samples. Thus, it is of interest to find a solution to the problem of service quality in call connections involving tandem codecs.

Two classes of solutions to the problem relating to the service quality in call connections involving tandem codecs have already been described and standardized, or are well in their way towards standardization. The earlier of the two methods, called Tandem-Free Operation (TFO), uses an in-band handshaking protocol to detect the presence of tandem codecs, and then proceeds to insert the compressed speech parameters within the 64 kb/s sample stream. This arrangement bypasses the requirement for decompression at the source codec and (re-)compression at the destination codec, which obviates the occurrence of errors at these two stages. As a result, a high quality of service can be achieved for a given end-to-end call between two mobile units. However, the standardized TFO approach provides no bandwidth advantage, as the full bandwidth ordinarily needed for the 64 kb/s sample stream is consumed for transmission of the compressed speech parameters.

A more recent approach, called Transcoder-Free Operation (TrFO), uses out-of-band signaling to detect call scenarios involving tandem codecs at call set-up time. Thereupon action is taken to put in place a direct end-to-end link to provide for a direct exchange of the compressed speech parameters without the involvement of network transcoders. However, while it provides for a savings and resource reduction compared to the standardized TFO

approach, the TrFO implementation suffers from the disadvantage of added cost and complexity due to, for example, the requirement for out-of-band signaling.

For more information on the TFO and TrFO techniques, the reader is invited to refer to the
5   following documents that are hereby incorporated by reference:

- 3rd generation partnership project, Technical specification group core network, Out of band transcoder control – Stage 2 (3GPP TS 23.153 V4.4.0 (2001-12));
- 3rd generation partnership project, Technical specification group core network, Bearer-
10   independent circuit-switched core network, Stage 2 (3GPP TS 23.205 V4.4.0 (2002-03));
- 3rd generation partnership project, Technical specification group (TSG) RAN3, Transcoder free operation (3GPP TR 25.953 V4.0.0 (2001-03));
- 3rd generation partnership project, Technical specification group services and system
15   aspects, Inband tandem free operation (TFO) of speech codecs, service description – Stage 3 (3GPP TS 28.062 V5.0.0 (2002-03));

It will thus be apparent that there is a need in the industry to provide a solution that is as robust and easy to implement, while also providing bandwidth and resource savings.
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Moreover, the use of conventional codec-bypass schemes such as TFO has heretofore been limited to enhancing the quality of calls established between two suitably enabled base station units in a mobile-to-mobile call. When one party is not so enabled, e.g., a telephone connected to a common packet-switched network via a network gateway, the use of
25   conventional codec-bypass techniques is not possible. It would therefore be an advantage to exploit the ability of one party's codec-bypass capabilities, even when the other party is not a suitably enabled base station unit.

In addition, the use of conventional codec-bypass schemes is often limited by the use of
30   backhaul gateways in a network, even when both parties to a call are codec-bypass-enabled base station units. Such gateways compress speech samples into a different format prior to transmittal of the formatted speech samples over a network. Unfortunately, when codec-bypass information is carried within the bit structure of the speech samples, the compression

effected by a backhaul gateway results in loss of the information and hence prevents advantageous usage of this facility. Hence, it would be beneficial to be able to allow tandem-free operation in circumstances where a backhaul gateway is used.

5   ## SUMMARY OF THE INVENTION

The present invention realizes that although an end-to-end codec-bypass connection along a given path between two endpoints may not be possible, it is nevertheless possible to achieve bandwidth savings by establishing a codec-bypass connection along only a portion of the
10   path.

Therefore, according to a first broad aspect, the invention seeks to provide a communication apparatus, comprising a first interface for exchanging data with a first neighboring entity, a second interface for exchanging data with a second neighboring entity, a memory for
15   storing codec information regarding the communication apparatus and a control entity operative to detect a first message from the first neighboring entity via the first interface, the first message being indicative of codec information regarding an originating entity. Responsive to detection of the first message, the control entity is operative to perform an assessment of compatibility between the codec information regarding the originating entity
20   and the codec information regarding the communication apparatus. Responsive to the assessment of compatibility being positive, the control entity is operative to self-identify the communication apparatus as a candidate for terminally supporting a subsequent codec-bypass negotiation with the originating entity. Responsive to the assessment of compatibility being negative, the control entity is operative to self-identify the
25   communication apparatus as a candidate for non-terminally supporting a subsequent codec-bypass negotiation with the originating entity.

According to a second broad aspect, the invention seeks to provide a method of establishing candidacy of a gateway as terminally or non-terminally supporting a codec-bypass
30   negotiation with an originating entity in a communications network. The method comprises detecting a first message received from a first neighboring entity, the first message being indicative of codec information regarding the originating entity; assessing compatibility between the codec information regarding the originating entity and the codec information

regarding the gateway; responsive to the assessment of compatibility being positive, self-identifying the gateway as a candidate for terminally supporting a subsequent codec-bypass negotiation with the originating entity; and, responsive to the assessment of compatibility being negative, self-identifying the gateway as a candidate for non-terminally supporting a

5   subsequent codec-bypass negotiation with the originating entity.

The invention also seeks to provide, in accordance with a third broad aspect, computer-readable media tangibly embodying a program of instructions executable by a computer to perform the above method of establishing candidacy of a gateway as terminally or non-

10   terminally supporting a codec-bypass negotiation with an originating entity in a communications network.

According to a fourth broad aspect, the present invention seeks to provide a method of establishing a codec-bypass connection between a first gateway and one of a plurality of in-

15   path gateways located along a path from the first gateway to a second gateway. The method comprises identifying a target in-path gateway from among the plurality of in-path gateways, the target in-path gateway being the in-path gateway furthest along the path from the first gateway which is characterized by codec-bypass connection compatibility with the first gateway, and establishing a codec-bypass connection between the first gateway and the

20   target in-path gateway.

The invention may also be summarized according to a fifth broad aspect as seeking to provide a method of establishing a codec-bypass connection along a path between a first gateway and a second gateway, the path comprising a plurality of in-path gateways. The

25   method comprises identifying a first sub-path between the first gateway and a first target in-path gateway from among the plurality of in-path gateways, the first target in-path gateway being the in-path gateway furthest along the path from the first gateway which is characterized by codec-bypass connection compatibility with the first gateway. The method also comprises identifying a second sub-path between the second gateway and a second

30   target in-path gateway from among the plurality of in-path gateways, the second target in-path gateway being the in-path gateway furthest along the path from the second gateway which is characterized by codec-bypass connection compatibility with the second gateway. The method further comprises determining the lengths of the first and second sub-paths and,

if the first sub-path is longer than the second sub-path, establishing a codec-bypass connection between the first gateway and the first target gateway, otherwise if the second sub-path is longer than the first sub-path, establishing a codec-bypass connection between the second gateway and the second target gateway.

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These and other aspects and features of the present invention will now become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying drawings.

10 *BRIEF DESCRIPTION OF THE DRAWINGS*

In the accompanying drawings:

Figs. 1A to 1D shows various call scenarios to which embodiments of the present invention

15 are applicable;

Fig. 2 is a message flow diagram illustrating various steps in establishing a codec-bypass connection in the scenario of Fig. 1A, in accordance with a specific embodiment of the present invention; and

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Figs. 3 to 8 show various alternative configurations to which embodiments of the present invention are applicable.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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In accordance with an embodiment of the present invention, arbitrary combinations of wireless / wireline gateways collaborate constructively to reduce bandwidth and delay, and to achieve higher voice quality by removing – to the extent possible – tandem codecs (or vocoders). The present description herein below describes a method to resolve the

30 disposition of the gateways that could find themselves involved in an codec-bypass connection. The gateways being given consideration are those which modify the speech payload (e.g. transcoding between different codec formats, including G.711).

With reference to Fig. 1A, a connection (e.g., a telephone call) is established between two endpoints A, B in a network consisting of a plurality of communication apparatuses hereinafter referred to as gateways. The network in question may include a circuit-switched network (e.g., the public switched telephone network – PSTN), a packet network or a combination thereof. Each of the endpoints A, B of the call may be either of a mobile station (wireless) or a land-based unit (wireline).

Various types of gateways are traversed by the call as it travels along subsequent legs of a call from one endpoint to another. The following definitions of various types of gateways have been provided for purposes of clarity, but without any intent to limit or otherwise restrict the scope of the present invention.

In particular, a "TDM gateway" is defined as a gateway that connects a circuit-switched network to a packet network. A "packet gateway" is defined as a gateway that connects only to a packet network. An "endpoint gateway" (or "termination gateway") is defined as a gateway located at an extreme end of the signal path. An example of an endpoint gateway is a UMTS gateway. In Fig. 1A, endpoint gateways include gateways A and B. Finally, an "in-path gateway" is defined as a gateway that is an intermediate node in the signal path (i.e. not an endpoint gateway). In Fig. 1A, in-path gateways include gateways 1, 2 and 3.

In general, a gateway comprises communications interfaces for communicating with neighbouring entities. In the case of an in-path gateway, the neighbouring entities are other gateways. Each gateway is configured to exchange signals in a variety of formats that are defined by a set of codecs with which the gateway is associated. Accordingly, each gateway is equipped with a memory element for storing codec information regarding the gateway in question. In the example of Fig. 1A, gateways A, 1 and 3 are associated with codec X, while gateway 2 is associated with codec Y and gateway B is associated with codec Z. It is noted that each gateway may be associated with more than one codec.

Once a call is established between the endpoints, the endpoint gateways attempt to establish a codec-bypass connection. This attempt is made through the exchange of codec-bypass negotiation messages during a codec-bypass negotiation. If the two endpoint gateways are associated with a common codec, then an end-to-end codec-bypass connection can indeed

be established through codec-bypass negotiation (or "dialogue"). This provides significant quality enhancement.

When the two endpoint gateways are not associated with a common codec, then one may
5   have recourse to a procedure whereby a codec-bypass connection is negotiated
("dialogued") for only a portion of the path that joins the endpoint gateways. This
procedure, which is described in greater detail herein below, results in bandwidth savings
and quality enhancement compared with the case where an attempt at establishing end-to-
end codec-bypass mode of operation would be altogether abandoned. In a specific
10 embodiment, the gateways along the path joining the endpoint gateways negotiate a codec-
bypass mode of operation connection for the longest possible portion of that path.

It is assumed, for the purposes of description, that the various in-path gateways along the
path are at least minimally codec-bypass compliant, without necessarily being able to
15 terminate a codec-bypass negotiation or connection. Specifically, depending on the
particular codec used by a remote entity and on the particular phase of a codec-bypass
negotiation, a gateway is assumed to be at least capable of acquiring a "passive" mode. A
gateway in "passive" mode is capable of relaying codec-bypass negotiation messages from
one leg to another leg of a call that it serves, but it does not terminate the negotiation, i.e., it
20 only serves to "passively support" a codec-bypass negotiation. However, depending on the
capabilities of the gateway, the gateway may also be able to acquire an "active" mode for
the purposes of the codec-bypass negotiation. In "active" mode, the gateway is capable of
terminally supporting (i.e., terminating) a codec-bypass negotiation on at least one leg of a
call that it serves. Thus, the gateway thus operates differently in passive mode and in active
25 mode, assuming that the active mode can be acquired for a given codec-bypass negotiation.

Fig. 2 illustrates a non-limitative example of operation of the present invention with respect
to the specific scenario in Fig. 1A. The following describes the coordination of the in-path
gateways 1, 2, 3 in response to codec-bypass negotiation messages initiated by endpoint
30 gateway A and subsequently exchanged amongst the various other gateways in the path
between endpoint gateways A and B. In particular, once a call is established, all codec-
bypass-compliant gateways will start monitoring the bearer to detect codec-bypass
negotiation messages. In addition to monitoring, those gateways that will have self-

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identified themselves as active will start transmitting codec-bypass negotiation messages. Optionally, the active in-path gateways can wait for a finite time period before initiating codec-bypass transmissions. This is meant to give priority to transmissions initiated by endpoint gateways.

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Thus, for example, at 220, endpoint gateway A starts by transmitting an initial codec-bypass negotiation message 202. The initial message 202 carries the codec information regarding endpoint gateway A, specifically a list of codec types and configurations supported by endpoint gateway A. In this case, the codec information identifies "codec X" as being supported at endpoint gateway A. Optionally, an endpoint gateway can provide a designated data element (e.g., a single bit) to identify its codec-bypass messages as having emanated from one end of the end-to-end connection in question.

When the ith in-path gateway (denoted GW(i) for convenience) receives the initial message 202 originated from endpoint gateway A, and if the codec type and codec configuration listed in the initial message 202 matches in-path GW(i)'s internally supported codec type and configuration, then in-path gateway GW(i) will return a response message towards endpoint gateway A through in-path gateways GW(i-1), GW(i-2), etc. The purpose of the response message is to signal to in-path gateway GW(i-1) and beyond (towards the endpoint gateway A) that in-path gateway GW(i) has the ability to support a compatible codec type and configuration. In-path gateway GW(i) thus goes through the process of identifying itself as a candidate gateway, capable of terminating the current codec-bypass negotiation with endpoint gateway A. In-path gateway GW(i) therefore self-identifies itself as an "active" gateway. However, as the response message travels towards endpoint gateway A, any previously determined active gateways in the chain will re-self-identify itself as a passive gateway upon receipt of the response message.

For example, at 222, in-path gateway 1, upon receipt of the initial message 202, realizes that it has a compatible codec type and configuration (namely, codec X). This causes the in-path gateway 1 to make a "mental note" of the fact that it is now active, i.e., in-path gateway 1 is now a candidate for terminating the codec-bypass negotiation with endpoint gateway A. The making of a "mental note" can take many forms, such as self-identification by way of setting a binary flag whose two states correspond to active and passive, respectively. This

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also results in in-path gateway 1 sending a response message 204 back to the endpoint gateway A. Meanwhile, gateway 1 forwards the initial message 202 towards in-path gateway 2.

5   At 224, in-path gateway 2, upon receipt of the initial message 202, realizes that it has does not have a codec type and configuration compatible with "codec X". In-path gateway 2 therefore plays the role of a passive gateway. Under such circumstances, in-path gateway 2 simply forwards the initial message 202 towards in-path gateway 3 without any indication back towards in-path gateway 1.

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At 226, in-path gateway 3, upon receipt of the initial message 202, realizes that it has a codec type and configuration compatible with "codec X". Accordingly, the in-path gateway 3 makes a "mental note" of the fact that it is now active, i.e., in-path gateway 3 is now a candidate for eventually terminating the current codec-bypass negotiation with endpoint

15   gateway A. Again, the making of a "mental note" can take many forms, such as self-identification by way of setting a binary flag whose two states correspond to active and passive, respectively. This also results in in-path gateway 3 forwarding the initial message 202 towards endpoint B, while sending a second response message 206 back to the in-path gateway 2.

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At gateway 2, being a passive gateway, the second response message 206 is simply forwarded to in-path gateway 1. However, a different effect is produced at in-path gateway 1, which had previously self-identified itself as active. The receipt of the second response message 206 by the in-path gateway 1 sigls to the in-path gateway 1 that a gateway further

25   down the chain towards endpoint gateway B is now active due to its capability of terminating the current codec-bypass negotiation. Therefore, in-path gateway 1 switches its mode of operation to ""passive".

The above-described process stops when a particular in-path gateway receives a message,

30   i.e. a codec-bypass message transmitted by endpoint gateway B, or when a self-identified candidate fails to receive any codec-bypass messages, e.g.. due to absence of the endpoint gateway B for end-to-end codec-bypass connection. In the former case, the self-identified candidate will go into passive mode only temporarily, in order to relay the codec-bypass

message back towards endpoint gateway A, so as to allow end-to-end codec-bypass negotiation. If the end-to-end negotiation between endpoint gateways A and B is successful, all in-path gateways, including the one that temporarily went into passive mode, remain in passive mode. However, in the case where there is no end-to-end codec-bypass

5   connection due to a negotiation failure, the last self-identified codec-bypass candidate will transmit a message in an attempt to start a codec-bypass negotiation with endpoint gateway A.

Thus, for example, at 228, endpoint gateway B does not have a codec type and

10   configuration compatible with "codec X". Therefore, endpoint gateway B either does not send a message back to gateway 3, or (as illustrated) endpoint gateway B sends a neg_fail message 208 (negotiation failure) towards in-path gateway 3. Receipt of the neg_fail message 208 and in-path gateway 3 signals to the in-path gateway 3 that it is the furthest gateway from endpoint gateway A that is capable of terminating the codec-bypass

15   negotiation. Accordingly, as shown in Fig. 1A, in-path gateway 3 negotiates a codec-bypass connection with endpoint gateway A.

Of course, it is also possible that no end-to-end codec-bypass connection is possible due to sheer absence of endpoint gateway B. This scenario, shown in Fig. 1B, causes basically the

20   same end result, with the active in-path gateway furthest along the path from endpoint gateway A transmitting a response message in an attempt to start negotiation of a codec-bypass connection with endpoint gateway A.

At the same time that endpoint gateway A attempts to dialogue with gateways further along

25   the path towards endpoint gateway B, endpoint gateway B itself may be attempting to dialogue with gateways further along the path towards endpoint gateway A. By completing analogous processes for both endpoint gateways A and B (and waiting until both options have been explored), a codec-bypass communication with the longest possible span from either endpoint can be established.

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As illustrated in Fig. 1C, there also could be a scenario in which the end-to-end codec-bypass negotiation fails due to codec mismatch, but where the possibility of overlap between two possible codec-bypass connections nonetheless exists. The two active in-path

gateways (from both ends) have knowledge if the end-to-end mismatch resolution was attempted or not (e.g., via presence or absence of exchanged request and acknowledge messages). After the active in-path gateways confirm the scenario, a codec-bypass solution can be provided. In short, codec-bypass negotiation between an in-path gateway with a

5   terminating gateway will not be disrupted by a codec-bypass attempt by the remote endpoint gateways.

Specifically, as per the existing codec-bypass decision algorithm or codec mismatch resolution rules, all codecs are ranked in preference. During the scenario being

10   contemplated, there are two incompatible codec types/configurations at endpoint gateways A and B, but each can establish a respective codec-bypass connection with a different one of the in-path gateways (namely in-path gateway 3 with endpoint gateway A and in-path gateway 2 with endpoint gateway B). An active in-path gateway which has identified itself as the codec-bypass candidate for termination of codec-bypass negotiation in one direction

15   but which supports a less preferred codec type/configuration will continue to send a response message (e.g., 204 or 206 in Fig. 2) in order to maintain its candidacy; however, it will refrain from initiating codec-bypass negotiation for a certain delay after the scenario is entered. This is meant to allow an active in-path gateway supporting the preferred codec type / configuration to initiate the codec-bypass negotiation first.

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In the example of Fig. 1D, if codec X is preferred to codec Y, then in-path gateway 3 will initiate a codec-bypass negotiation with terminating gateway A while in-path gateways 1 and 2 remain passive. Both in-path gateways 2 and 4 can initiate codec-bypass negotiation with endpoint gateway B after the specified delay. If there is no codec-bypass connection

25   established across in-path gateway 2, in-path gateway 2 may optionally transmit a message to initiate a codec-bypass negotiation with endpoint gateway B. However, as is the case in the illustrated embodiment, a codec-bypass connection is established between endpoint gateway A and in-path gateway 3, which means that in-path gateway 2 self-identifies itself as passive. Therefore, in-path gateway 4 will not receive the response message (204 or 206)

30   from in-path gateway 2 and will therefore remain self-identified as active, i.e., it is a candidate for terminating the codec-bypass negotiation with endpoint gateway B. (This design is applicable to all other in-path gateways in the chain supporting codec Y.) In this manner, the furthest in-path gateway from endpoint B which supports codec Y and is

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outside the codec-bypass connection between endpoint gateway A and in-path gateway 3 is sought for the purposes of initiating codec-bypass negotiation with in-path gateway 4. In the illustrated embodiment, this title is held by in-path gateway 4, which supports codec Y and is outside the codec-bypass connection between endpoint gateway A and in-path

5   gateway 3. As a result, two separate non-overlapping codec-bypass connections can be established. Generally speaking, the present invention allows for more than one segment of codec-bypass negotiations.

An in-path gateway that detects codec-bypass negotiation messages only from one "side"

10   (as viewed in the orientation in Figs. 1A-1D and 2) can become a codec-bypass termination point. If codec-bypass transmissions are detected on both sides (labeled "left" and "right" sides for Packet GW, and "packet" and "TDM" for TDM GW), the behavior of (active) gateways is determined based on the mutual vocoder compatibility of the two remote nodes, as well as that of the gateway itself. Tables 1-4 define the behavior of Packet and TDM

15   gateways under specific embodiments of the present invention.

As an enhancement, a data element (e.g., a single bit) can be used to identify cases in which a gateway needs to receive traffic in the "original" compression format (i.e. compression format at the time of call setup – e.g., G.711) even after establishment of a codec-bypass

20   connection. This bit can be used in two cases. Firstly, it will be used by passive gateways to make sure that adjacent gateways will continue to send them the traffic signal in the original format (e.g., G.711) as well as in other compressed formats after the establishment of a codec-bypass connection. Secondly, this bit will also be used by active TDM gateways that may not be able to support the codec selected for establishment of a codec-bypass

25   connection, to request that adjacent gateways continue to send them the traffic signal in the original format (e.g., G.711) as well as in other compressed formats after the establishment of a codec-bypass connection.

30   **Table 1: Packet gateway codec compatibility when adjacent gateways do not require original codec format**

Legend:

GW / Left: This column indicates whether or not the gateway and the "left"-side end node have common codecs

GW / Right: This column indicates whether or not the gateway and the "right"-side end node have common codecs

Left / Right: This column indicates whether or not the left- and right-side end nodes have common codecs with each other (but not necessarily with the gateway)

Y: the two entities have at least one compatible vocoder

N: the two entities have no compatible vocoders

X: It makes no difference whether or not a compatible vocoder exists

GW / Left	GW / Right	Left / Right	Resolution
X	X	Y	Gateway is passive towards both end nodes. "Left" and "Right" switch to common codec
Y	Y	N	Depending on the availability of CPU resources, gateway can be active towards either or both end nodes independently to achieve bandwidth and/or delay optimization
N	Y	N	Gateway is active towards right-side end node
Y	N	N	Gateway is active towards left-side end node
N	N	N	Gateway is passive towards both end nodes. Codec-bypass negotiation cannot be terminated with either end.

Table 2: TDM Gateway codec compatibility when adjacent packet gateway and TDM-side node do not require original codec format

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Legend:

GW / Packet: This column indicates whether or not the gateway and the packet-side end node have common codecs

GW / TDM: This column indicates whether or not the gateway and the TDM-side end node have common codecs

Packet / TDM: This column indicates whether or not the packet- and TDM-side end nodes have common codecs with each other (but not necessarily with the gateway)

Y: the two entities have at least one compatible vocoder

N: the two entities have no compatible vocoders

X: It makes no difference whether or not a compatible vocoder exists

GW / Packet	GW / TDM	Packet / TDM	Resolution
Y	Y	Y	Gateway is passive towards both end nodes. Packet-side and TDM-side end nodes switch to common codec.
N	N	Y	Gateway is passive towards both end nodes. Codec-bypass negotiation cannot be terminated with either end node, although end-to-end codec-bypass negotiation may transit the gateway. Sets bit to indicate (to packet side) that it requires traffic in the format that was in use at call setup
N	N	N	Gateway is passive towards both end nodes. Codec-bypass negotiation cannot be terminated with either end node
Y	N	N	Gateway is active towards packet-side end node
Y	N	Y	Gateway is active towards packet-side end node. Alternatively, gateway can remain passive to allow codec-bypass negotiation to transit the gateway. In such case, set bit to indicate (to packet side) that traffic is required in the format that was in use at call setup

N	Y	N	Gateway is active towards TDM-side end node
N	Y	Y	Gateway is active towards TDM-side end node. Alternatively, gateway can remain passive to allow codec-bypass negotiation to transit the gateway. In such case, set bit to indicate (to packet side) that traffic is required in the format that was in use at call setup

Table 3: Packet gateway codec compatibility when "left" gateway requires original codec format

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Legend:
GW / Left: This column indicates whether or not the gateway and the "left"-side end node have common codecs
GW / Right: This column indicates whether or not the gateway and the "right"-side end node have common codecs
Left / Right: This column indicates whether or not the left- and right-side end nodes have common codecs with each other (but not necessarily with the gateway)
Y: the two entities have at least one compatible vocoder
N: the two entities have no compatible vocoders
X: It makes no difference whether or not a compatible vocoder exists

GW / Left	GW / Right	Left / Right	Resolution
Y	Y	Y	Gateway is active towards the right-side end node and towards the left-side end node
Y	N	Y	Gateway is passive towards both end nodes. Sets special bit towards "right" to indicate the need to support original codec format. Codec-bypass negotiation will transit the gateway

N	Y	Y	Gateway is passive towards both end nodes. Sets special bit towards "right" to indicate the need to support original codec format. Codec-bypass negotiation will transit the gateway. Alternatively, gateway can be active towards the right-side end node
N	N	Y	Gateway is passive towards both end nodes. Sets special bit towards "right" to indicate the need to support original codec format. Codec-bypass negotiation will transit the gateway
N	N	N	Gateway is passive towards both end nodes. Codec-bypass negotiation cannot be terminated with either end node
Y	N	N	Gateway will be active towards the left-side end node
N	Y	N	Gateway will be active towards the right-side end node
Y	Y	N	Depending on CPU availability, gateway will be active towards the left-side end node and/or the right-side end node

Table 4: TDM gateway codec compatibility when adjacent packet gateway requires original codec format

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Legend:
GW / Packet: This column indicates whether or not the gateway and the packet-side end node have common codecs
GW / TDM: This column indicates whether or not the gateway and the TDM-side end node have common codecs

Packet / TDM: This column indicates whether or not the packet- and TDM-side end nodes have common codecs with each other (but not necessarily with the gateway)

Y: the two entities have at least one compatible vocoder

N: the two entities have no compatible vocoders

X: It makes no difference whether or not a compatible vocoder exists

GW / Packet	GW / TDM	Packet / TDM	Resolution
Y	Y	Y	Gateway is passive towards both end nodes
N	N	Y	Gateway is passive towards both end nodes. Codec-bypass negotiation cannot be terminated with either end node, although end-to-end codec-bypass negotiation may transit the gateway. Sets bit to indicate (to packet side) that it requires traffic in the format that was in use at call setup
N	N	N	Gateway is passive towards both end nodes. Codec-bypass negotiation cannot be terminated with either end
Y	N	N	Gateway is active towards the packet-side node
Y	N	Y	Gateway is active towards packet-side end node. Alternatively, gateway can remain passive to allow codec-bypass negotiation to transit the gateway. In such case, set bit to indicate (to packet side) that traffic is required in the format that was in use at call setup
N	Y	N	Gateway is active towards the TDM-side node
N	Y	Y	Gateway is active towards TDM-side end node. Alternatively, gateway can remain passive to allow codec-bypass negotiation to transit the gateway. In such case, set bit to indicate (to packet side) that

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			traffic is required in the format that was in use at call setup
Y	Y	N	Depending on the availability of CPU resources, gateway can be active towards either or both end nodes independently to achieve bandwidth and/or delay optimization

It should be understood that other modifications of, and additions to, the present invention are possible. For example, the self-identification process described herein above is applicable to the various example, non-limiting scenarios depicted in Figs. 3 to 8.

Also, it is recalled that the rules and procedures above essentially lead to clarification of a particular in-path gateway's disposition. Specifically, a codec-bypass-compliant in-path gateway will know whether or not it is the last in-path gateway and whether or not it has vocoders common with each of the endpoints. Equipped with this information, should a codec-bypass connection fail to establish due to the absence of a compatible codec type or configuration at either end, the above methods can be applied recursively in order to come up with codec-bypass connection segments where applicable, for the purpose of reducing bandwidth where applicable. The recursive application of the procedure means that the last in-path gateways (rather than the endpoint gateways) would initiate their own search for codec-bypass partners based on their full suite of supported vocoders. In initiating the codec-bypass handshaking these gateways will also take advantage of their knowledge of the vocoders supported by the endpoints to achieve maximum bandwidth savings and voice quality. A pre-defined vocoder order of preference will guide the application of the procedure, e.g., in situations where each of the two last in-path gateways supports the vocoder of different endpoints only. The prescribed order of vocoder preference will determine which of the two last in-path gateways will initiate the new round of codec-bypass handshaking. The in-path gateway which supports a vocoder with a lower priority will wait for a prescribed period of time before initiating its own codec-bypass handshaking. This priority scheme prevents race conditions that may lead to instability.

Should the procedure initiated by the last in-path gateways fail to achieve codec-bypass mode of operation due to the absence of common vocoders, the recursion can be applied again to search for yet more limited application of codec-bypass mode of operation. Thus, the in-path gateways can identify themselves to be in the middle of the path, rather than the last in-path gateway, by monitoring codec-bypass exchanges around them including the usage of a suitable message. Again, the procedure may result in several segments of codec-bypass negotiations, i.e. not limited to a single segment.

Those skilled in the art will appreciate that the control entity of each gateway may be implemented as an arithmetic and logic unit (ALU) having access to a code memory (not shown) which stored program instructions for the operation of the ALU. The program instructions could be stored on a medium which is fixed, tangible and readable directly by the processor, (e.g., removable diskette, CD-ROM, ROM, or fixed disk), or the program instructions could be stored remotely but transmittable to the processor via a modem or other interface device (e.g., a communications adapter) connected to a network over a transmission medium. The transmission medium may be either a tangible medium (e.g., optical or analog communications lines) or a medium implemented using wireless techniques (e.g., microwave, infrared or other transmission schemes).

Those skilled in the art should also appreciate that the program instructions stored in the code memory can be compiled from a high level program written in a number of programming languages for use with many computer architectures or operating systems. For example, the high level program may be written in assembly language, while other versions may be written in a procedural programming language (e.g., "C") or an object oriented programming language (e.g., "C++" or "JAVA").

Those skilled in the art should further appreciate that in some embodiments of the invention, the functionality of the control entity may be implemented as pre-programmed hardware or firmware elements (e.g., application specific integrated circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), etc.), or other related components.

While specific embodiments of the present invention have been described and illustrated, it will be apparent to those skilled in the art that numerous modifications and variations can be made without departing from the scope of the invention as defined in the appended claims.